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PROCEDURES FOR CONDUCTING A FIELD EVALUATION OF NIGHT VISION GOGGLE COMPATIBLE COCKPIT LIGHTING

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The requirements to assess the compatibility of aircraft cockpit lighting with night vision goggles (NVGs) are defined in MIL-L-85762A, Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible. However, the procedures specified to evaluate cockpit lighting are primarily specific to the laboratory environment, with only a few assessments specific to the field environment. This report describes the procedures used by Armstrong Laboratory's Aircrew Training Research Division (AL/HRA) to conduct a field evaluation of aircraft cockpit lighting. The evaluation procedures are divided into Planning, Evaluation Preparation, Assessment Procedures, and Reporting Results. This report can also be used as a guideline for other organizations that need to conduct NVG-compatible cockpit lighting evaluations.

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PREFACE

This work was conducted by the Armstrong Laboratory, Aircrew Training Research Division (AL/HRA), with support from Hughes Training, Inc., Training Operations (HTI). Both are located in Mesa, Arizona. This work was conducted under Work Units 1123-B4-01, Night Vision Device Training Research, and 1123-B2-06, Aircrew Training Research Support. HTI, working under contract F41624-95-C-5011, supports AL/HRA by supplying night vision device (NVD) subject matter expertise in the areas of NVD research, development, test and evaluation.

This report documents the procedures used by AL/HRA to conduct a field evaluation of cockpit lighting to determine its compatibility with night vision goggles (NVGs). The procedures assess cockpit lighting according to standards outlined in MIL-L-85762A, Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible.

AL/HRA gratefully acknowledges the support of the Systems Engineering Test Directorate of the Naval Air Warfare Center (NAWC) - Aircraft Division at Patuxent River, MD. Many of the procedures described in this report were developed by NAWC.

PROCEDURES FOR CONDUCTING A FIELD EVALUATION OF NIGHT VISION GOGGLE COMPATIBLE COCKPIT LIGHTING

INTRODUCTION

This report describes procedures used by the Aircrew Training Research Division, Armstrong Laboratory (AL/HRA), Mesa, AZ, when performing a field evaluation of cockpit lighting that has been modified or designed to be compatible with night vision goggles (NVGs). The procedures determine if the cockpit lighting meets the requirements defined in MIL-L-85762A, Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible. Most of the procedures are similar to those developed by the Systems Engineering Test Directorate, Naval Air Warfare Center (NAWC) - Aircraft Division, Patuxent River, MD.

MIL-L-85762A describes 16 Quality Assurance Provisions (QAPs) that determine the compatibility of cockpit lighting. The QAPs consist of laboratory bench tests for measurement of specific lighting components, evaluations of mockup cockpit lighting systems for preproduction aircraft, and field assessments of cockpit lighting systems for production and modified aircraft. Because most evaluations are performed on modified aircraft currently fielded, logistics (e.g., availability of facility, aircraft, and/or NVG experienced subjects, etc.,) often limit extensive data collection. Therefore, the QAPs have been prioritized and four critical QAPs chosen by AL/HRA and NAWC to determine cockpit lighting compatibility: Daylight Readability, Nighttime Readability, NVG-Aided Visual Acuity (VA) and NVIS Radiance (NR). The four QAPs provide a good balance of objective and subjective data for determining the acceptability of NVG-compatible lighting modifications.

PLANNING

Planning is critical to ensure a thorough evaluation of the cockpit lighting. Since most evaluation facilities cannot be sufficiently darkened during daytime to obtain appropriate ambient light levels for the evaluation, most evaluations are performed during nighttime. It is important to relay this to the requesting agency to ensure the availability of support personnel for the evaluation. The following should be accomplished as early as possible:

Personnel and Facilities

a. Obtain name(s) of personnel from requesting agency who will assist or monitor the evaluation.

b. Determine dates and times for the evaluation(s).

c. Submit requirements for evaluation facilities and support personnel. It is recommended that evaluation personnel travel to the facility at least 30 days prior to the evaluation to determine its suitability (Appendix A).

d. Determine what equipment is required for the evaluation and ensure its availability (Appendix B).

e. Determine the type of report(s) required (e.g., Preliminary, Quick Response, Final).

f. Determine the date required for submission of report(s) (e.g., within 30 days after the completion of the evaluation).

Aircraft Information. Have the requesting authority forward the following information as soon as possible:

a. Aircraft make(s)/model(s).

b. NVG to be used in the aircraft (Type I or Type II/ Class A or Class B).

c. Cockpit layout including location of all instruments, displays, warning/caution/ advisory lights, floodlights, and other lights that have been modified. Normally this requires a copy of the cockpit layout from the aircraft flight manual.

d. Documentation of the following for each display, indicator, panel, etc:

(1) Class of lighting (Class A or Class B).

(2) Type of modification (e.g., filter, post light, bezel, etc.).

(3) Identification of items that will be illuminated only with floodlights.

(4) Manufacturer and/or vendor for each modified lighting component and copies of their cockpit blueprints.

e. Any additional assessments to be performed during the evaluation (e.g., comparison of different filter materials). These may be defined in the Technical Requirements Document specific to the contract.

Standards. Review applicable military specifications to ensure compliance and have them readily available during the evaluation.

Data Sheets. Develop data sheets for each of the four QAP assessments planned. The data sheets should contain an ordered list of each individual component or system being assessed (see Appendix C for examples). To save time, results should be entered into the computer immediately after the completion of each assessment.

EVALUATION PREPARATION

Prior to the night of the evaluation, prepare the facility with the modified aircraft in position.

Stands. Place stands in position. For fighter/attack aircraft, one stand should be positioned on each side of the aircraft to allow easy access to the cockpit and another stand positioned in front of the aircraft 20 feet from the planned pilot's eye position. The front stand will be used by personnel assigned to manipulate the NVG resolution chart during the NVG-aided VA assessment. Once the stand has been positioned, mark its location on the floor with tape so it can be easily and accurately repositioned if it has to be moved. Separate stands may be placed at different locations (e.g., 45 degrees right or left) if other VA measurements are planned. If one stand is to be used at different locations, marking those locations during the preparation phase would ensure accurate and rapid placement in a dark environment.

Equipment. Place all equipment in a location that provides easy access.

AC Power. Ensure 110 AC extension cords are available for appropriate equipment.

Aircraft Power. Ensure external aircraft power is available and serviceable. Power will be required for aircraft lighting and canopy operation.

Aircraft Lighting. Ensure aircraft lighting is operable; locate and become familiar with cockpit lighting controls.

Cockpit Communication. Ensure voice communication with the person in the cockpit will be available and operable for assessment of NVG-aided VA. Headsets with microphones may be used by personnel outside the cockpit, but personnel in the cockpit will use flight helmets because NVGs will be operated.

Hangar Controls. Determine the location of controls for hangar lights and for operating hangar doors. Ensure permission is obtained for operating the doors or ensure an authorized person is present during the evaluation.

Office Space. Determine the location of office space and ensure a telephone is available.

ASSESSMENT PROCEDURES

As previously mentioned, the four assessments yield both objective and subjective data. For subjective assessments as many subjects as possible should be used, but logistics will ultimately determine the number of subjects available. For objective assessments, at least three measurements should be obtained and averaged for the final value.

The facility requirements differ between the four assessments. However, for efficiency one facility should be used for all assessments. The facility must be light-tight; this is defined as an enclosure that limits ambient illumination to no greater than 1.7×10^{-10} NR_A for Class A NVGs. An NVG representative of the type to be used in the aircraft shall be used to view all areas in the interior of the facility, and any significant light leaks should be covered to minimize visibility to the NVG. If excessive light leaks are suspected, target NR due to light leaks must be measured. In general, most facilities meet the light-tight criterion only during nighttime hours.

Daylight Readability. Daylight readability must be assessed on all modified lighting systems. Filters intended to make cockpit lighting NVG-compatible often result in reduced display contrast and reduced attensity (the ability to attract attention) during daytime. The assessment methods for daylight readability are specified in MIL-L-85762A and MIL-S-22885E, General Specification for Switches, Push Button, Illuminated.

Daylight readability is assessed using simulated sunlight. As a result, a light tight facility is not required for the assessment and may be performed during daytime. The assessment is conducted using a sunlight simulation device (sun gun) developed at AL/HRA. The device consists of a 300-watt projection bulb in a metal casing with a small fan to prevent overheating and is used in conjunction with a Minolta T-1H illuminance meter. The illuminance meter is placed immediately adjacent to the cockpit displays being evaluated, and the sun gun is directed at the meter. The sun gun's distance from the meter is varied until a value of 10,000 foot candles (fc) is indicated on the meter display, then daylight readability is assessed. Interested organizations should contact AL/HRA for instructions to develop a sun gun.

NOTE: (1) Although the military specifications define daylight readability measurement conditions as light incident from 30 degrees to create both diffuse and specularly reflected luminance, the field evaluation examines light incident from any angle that is operationally relevant. This is a more stringent test than that defined in MIL-L-85762A; however, it is necessary to ensure adequate readability. It is AL/HRA's experience that high quality filters will pass this assessment. (2) The military specifications define daylight readability in terms of luminance contrast of characters when illuminated to 10,000 fc. Luminance contrast is not easily measured in the field, and therefore, only subjective evaluations are conducted.

Qualified subjects (number dependent upon time available) assess daylight readability with the cockpit displays adjusted at an operationally representative level, and only displays that were modified with filters are evaluated. The subjects may be crewmembers or experienced

evaluation personnel (e.g., NVG instructor pilots from AL/HRA) and should have at least 20/20 Snellen acuity. The subjects observe the displays while the sun gun is positioned at various angles and comment on the readability of the displays. The responses are recorded on data sheets. This procedure is best performed using three individuals: the subject, one person positioning the sun gun and illuminance meter, and one person collecting data.

Nighttime Readability. Nighttime readability is part of the unaided visual inspection specified in MIL-L-85762A. This is a subjective determination of the readability of the displays under nighttime operational conditions. Displays also are evaluated for attensity and the presence of shadowing. This assessment should be conducted in a darkened facility.

As with daylight readability, subjects assess nighttime readability. Prior to commencing assessment, each subject dark adapts for a minimum of 15 minutes, then adjusts the cockpit lighting to an operationally representative level. With the subject seated in the cockpit, the data gatherer consults the data sheets and tells the subject which panel, display, etc., to view. Subject comments on readability and the cause of any deficiencies are recorded. If a deficiency is noted, the luminance of the display is measured. MIL-L-85762A specifies that uniformity of luminance between lighting components be within a 2:1 ratio of dim to bright light. There is no uniformity requirement in MIL-L-85762A for luminance within a display. However, a requirement may be defined in the contract for the modification, and luminance should be measured if a deficiency is noted. The luminance measurements are made with a Minolta LS-110 photometer; a Hoffman Engineering SRS-2 reflectance standard is used to measure floodlight uniformity.

NVG-Aided Visual Acuity. MIL-L-85762A specifies that a resolution target be illuminated such that 1.7×10^{-10} NR_A (for Class A NVGs) or 1.6×10^{-10} NR_B (for Class B NVGs) is reflected from the white portion of the target. NVG-aided VA measurements are obtained with a subject seated in the cockpit with the cockpit lighting adjusted to an operationally representative level. No detectable degradation in VA due to the cockpit lighting should be observed. If degradation exists, the incompatible light source(s) should be identified. The NVG used during the evaluation should be representative of the NVG planned for use in the aircraft. The assessment should be conducted in a light-tight facility (see Appendix A).

AL/HRA has measured NVG-aided VA using one of two methods. The first method is similar to that described in MIL-L-85762A. NVG-aided VA measurements are obtained using a modified 50% contrast (measured as contrast modulation [Luminance_{max} - Luminance_{min}]/[Luminance_{max} + Luminance_{min}]) NVG Resolution Chart developed for cockpit lighting evaluations by Armstrong Laboratory. The NVG chart (see Fig. 1) contains 16 horizontally and vertically oriented square wave grating patterns which determine Snellen acuities of 20/20, 20/25, 20/30, 20/35, 20/40, 20/45, 20/50, 20/55, 20/60, 20/65 and 20/70 when resolved at a viewing distance of 20 feet. The patterns are randomly distributed on the NVG chart, and the 20/35 through 20/55 patterns are presented twice. The NVG chart was developed as an alternative to the USAF 1951 Medium Contrast Resolution Resolving Power Target (USAF Tri-

Figure 1
NVG Resolution Chart

Figure 2
USAF Tri-bar Chart

bar Chart) specified in MIL-L-85762A. This was done to overcome possible decision biases and limitations when viewing the USAF Tri-bar Chart. For example, the USAF Tri-bar Chart (see Fig. 2) is organized so that a standard pattern (three horizontal bars adjacent to three vertical bars) along with an identifying number is repeated throughout the chart. Thus, the solution to the pattern is always known to the viewer. The Tri-bar Chart procedure requires a highly subjective determination of whether or not a pattern can be resolved. Because the pattern does not change, a subject's decision may be biased. In comparison, the NVG chart can be randomly oriented and requires the viewer to identify the orientation of the pattern. This procedure helps to overcome decision bias.

At least two subjects should be used for the determination of NVG-aided VA. However, because subjects may differ in their operationally representative adjustment of light levels, more subjects should be used if possible. Each subject "reads" the NVG chart resolution patterns from left to right and top to bottom under each of the four possible chart orientations. Each pattern is viewed four times (except for patterns 20/35 through 20/55 which are viewed eight times due to their replication on the chart). The subjects indicate whether a pattern is vertical, horizontal, or cannot be resolved. The number of correct vertical and horizontal responses are totaled, and VA values are determined via a 75% correct criterion. For example, if a subject correctly identifies the 20/55 pattern 100% of the time (8 of 8), the 20/50 pattern 75% of the time (6 of 8) and the 20/45 pattern 62.5% of the time (5 of 8), the subject's VA is assessed as 20/50. NVG-aided VA for each measurement condition is averaged across all subjects.

A <u>second</u> method for measuring NVG-aided VA uses a computerized procedure. NVG-aided VA measurements are recorded using 50% contrast resolution targets generated on a Macintosh Classic computer. The computer randomly generates 45-degree left- and right-oriented square-wave grating patterns that vary in 5% increments of Snellen acuity (i.e., 20/xx). A staircase method is used in which the resolution targets increase or decrease in spatial frequency as a function of the correctness of the subject's responses (i.e., whether the orientation is "right" or "left"). This computerized procedure determines the resolution target that can be correctly identified approximately 75% of the time.

These procedures used to measure NVG-aided VA offer a compromise between accuracy and efficiency. A 50% correct detection value can be identified in a shorter period of time, is greatly influenced by chance (guessing), and therefore is not operationally meaningful. On the other hand, a 100% correct detection threshold, while more operationally meaningful, requires significantly more time to determine. Since time is limited during cockpit lighting evaluations, choosing a correct detection threshold of approximately 75% to assess NVG-aided VA provides a meaningful and reliable determination in approximately 5 to 10 minutes. The measurement of VA is a psychometric assessment and the 75% threshold is consistent with standard practices. Even though the computerized procedure takes slightly longer, it provides more control over VA determination than the procedure using the NVG chart.

During the evaluation, the NVG chart or computer monitor is placed 20 feet from the eyepoint of the subject seated in the cockpit and is illuminated by a Hoffman LM-33-80 Starlight Projector. The illumination level is adjusted so that NVIS radiance measured from the white portion of the target is equivalent to 1.7×10^{-10} NR_A or 1.6×10^{-10} NR_B. This is measured with a Pritchard 1530-AR spot photometer with a Class A or B filter and verified with a Hoffman Engineering NVG-103 inspection scope. If the computer is used, the output radiance is adjusted so that the proper NVIS radiance is also obtained.

Prior to the assessment of NVG-aided VA, the subjects adjust the NVG to obtain maximum VA by viewing a high contrast NVG chart under full-moon conditions. The NVG chart is placed in the same location as the VA assessment charts, and NVG adjustments are made while in the cockpit with no obstructions (e.g., head-up display [HUD] combiner or canopy) between the subject and the chart. After the NVG is adjusted, the NVG-aided VA measurements are taken under the planned viewing and cockpit lighting conditions. While measurement conditions will be specific to the aircraft type, the following measurements are usually performed in all aircraft in the following order: (a) unobstructed (over or around all transparencies), (b) baseline condition (through the transparencies with cockpit lighting extinguished), and (c) trial condition (through the transparencies with the cockpit lighting illuminated). If any VA degradation occurs between measurements (b) and (c), then additional measurements are made with individual lighting components or combinations of components illuminated to identify the source(s). Other measurement conditions may include: through the unpowered head-up display (HUD) combiner (to assess HUD combiner transmission effects), through the illuminated HUD combiner (to assess the effect of HUD phosphor emission), or through certain areas of the canopy, window, or windscreen (to assess transparency curvature effects or effects of light reflections). These measurements may require the repositioning of the stand. Care should be taken to maintain the 20-ft viewing distance. A diagram of an assessment configuration used for an F-16 evaluation is presented in Figure 3.

Figure 3
Configuration for Assessment of NVG-aided Visual Acuity
Used in a Previous F-16 Evaluation

NVIS Radiance. MIL-L-85762A specifies that NR be measured from the cockpit displays. NR theoretically represents the amount of energy within the spectral response of the NVGs that would be reflected from a defoliated tree under starlight conditions. MIL-L-85762A establishes NR limit values to ensure that the cockpit lighting is no brighter than the outside scene during this operating condition. NR limit values are specified in Table IX of MIL-L-85762A and are established for both Class A (NR_A) and Class B (NR_B) NVGs. Any lighting that produces radiance greater than the specified NR value is incompatible by definition.

NR is measured using a Hoffman NVG-103 Inspection Scope. The cockpit lighting is adjusted to an operationally representative level by a dark-adapted subject and then measured by the evaluator using the inspection scope. The inspection scope's internal reference source is adjusted to the NR limit value (1.7×10^{-10} NR_A or 1.6×10^{-10} NR_B) specified in MIL-L-85762A. The cockpit is scanned to identify any light sources appearing brighter than the reference source. Any bright light sources are then measured, and the results are recorded on data sheets. **NOTE:** MIL-L-85762A specifies that a spectroradiometer be used to measure radiance, and that NR then be computed. Because of their size, it is not feasible to take spectroradiometers into the field. Although the NVG-103 is not as accurate as a spectroradiometer, it is specifically designed for making field measurements. NR is usually the last assessment of the evaluation because, unlike daylight readability, nighttime readability, or NVG-aided VA, the results are less likely to be affected by evaluator fatigue.

To derive NR values, MIL-L-85762A requires that the brightness of primary and secondary displays be adjusted to produce 0.1 foot-Lambert (fL), and the brightness of monochromatic electronic and electro-optical displays be set to produce 0.5 fL. However, during lighting evaluations, the displays are adjusted to operationally representative levels, and their luminance values are measured with a photometer. The actual luminance values may or may not cqual the specified luminance values. MIL-L-85762A allows a scaling factor (specified luminance divided by measured luminance) to be used to adjust the NR value to match the operationally representative luminance. The scaling factor can influence the overall determination of NR. For example, a measured luminance greater than the specified luminance will produce a small scaling factor. When that scaling factor is multiplied by the measured NR, the result is a smaller overall NR value. Luminance measurements for the evaluation are obtained using a Minolta LS-110 photometer with a #110 close-up lens having an aperture of 0.5 mm at minimum focus distance. Because a scaling factor is used in the calculation, it is not necessary to use the same operationally representative levels from the NVG-aided VA assessment for the NR assessment.

REPORTING RESULTS

A report describing the results of the evaluation should be submitted to the sponsoring agency no later than 30 days after the evaluation. The report should detail deficiencies in meeting the requirements defined in MIL-L-85762A or those specified in the contract for the modification. Based upon the evaluator's experience, an attempt may be made to prioritize any deficiencies noted and make recommendations when applicable. However, if deficiencies need to be categorized for impact upon aircraft operations, other organizations (i.e., aircraft operators, and Systems Program Offices) should be involved in the decision process. The report should be written for readers with little or no NVG experience, describing the evaluation procedures with background information on NVG operations as well as aircraft modifications that were evaluated. Cockpit lighting components should be referred to according to the labels presented in the aircraft flight manual (e.g., a fire warning indicator may be labeled as "ENG FIRE and ENGINE Warning Light"). An example of background information to be included in a report is presented in Appendix D.

APPENDIX A: EVALUATION FACILITY

To determine a facility's suitability, the following conditions and/or items should be available:

1. Light-tightness.

2. Three B-1 or B-4 stands. (Larger stands may be required for aircraft larger than a C-130.)

3. Alternating current (AC) electrical power for powering measurement instruments.

4. An external power cart for powering aircraft.

5. A cooling cart for aircraft avionics (if applicable).

6. A minimum of a 30-ft arc 180 degrees around the aircraft cockpit for NVG-aided VA measurements and stand placement.

7. An equipment storage location.

8. Headsets/microphones (one inside cockpit and two outside cockpit with extension cords).

9. Office space separate from the evaluation area.

APPENDIX B: EQUIPMENT LIST

1. Sunlight simulation device

2. Minolta T-1H Illuminance Meter

3. NVG resolution charts (high contrast 20/20 for NVG adjustment and 50% contrast for NVG-aided VA assessment)

4. Hoffman Engineering LM-33-80 Starlight Projector

5. Hoffman Engineering NVG-103 Inspection Scope

6. Pritchard 1530-AR NviSpot Photometer

7. Minolta LS-110 Photometer with #110 Close-up Lens

8. Hoffman Engineering SRS-2 Spectral Reflectance Standard

9. NVGs, batteries, mounts, and helmets (two sets of each)

10. Tripods (3)

11. Extension cords (two, one at least 50 ft+)

12. Macintosh Classic Computer w/software for target generation (optional)

13. Clipboards (2)

14. Preprinted data sheets

15. NVG compatible flashlights (4)

16. Tape measure (minimum 50 ft)

17. Tape for sealing light leaks and for cockpit use

18. Black cloth (10 sq ft)

APPENDIX C: EXAMPLE OF DATA SHEETS

DAYLIGHT READABILITY DATA SHEET

AIRCRAFT/CONDITION____

____

SUBJECT__________________________

DISPLAY/CONDITION	**COMMENTS**	**fc WHERE READABLE**
MASTER CAUTION LIGHT		
A/I and SAM INDICATORS		
MASTER MODE CONTROLS/ MARKER BEACON PANEL		
FIRE WARNING/ EXTINGUISHING PANEL		
LANDING GEAR CONTROL HANDLE & 3 LIGHTS		
FLAP POSITION INDICATOR		

NIGHTTIME READABILITY DATA SHEET

AIRCRAFT/CONDITION____

____

SUBJECT________________________

DISPLAY/CONDITION	DISPLAY SPECIFIC COMMENTS	UNIFORMITY COMMENTS
RT CONSOLE FLOOD-LIGHTS		
ENGINE PANEL		
OXYGEN PANEL		
OXYGEN SUPPLY		
CMD PANEL		
ENGINE START PANEL		
INTERIOR LIGHT PANEL		

NVIS RADIANCE DATA SHEET

ITEM	LUM. MEAS.(fL)	LUM. REQ'D. (fL)	NR MEASURED (NR_A or NR_B)	NR SCALED ($NR_{\underline{A}}$ or NR_B)	MAX NR ALLOWED ($NR_{\underline{A}}$ or NR_B)

NVG-AIDED VISUAL ACUITY DATA SHEET

NAME ________________________ **NVG**______________________

CONDITION____

ACTUAL VALUES:

Orientation 1	Orientation 2	Orientation 3	Orientation 4
H V H H	V V H H	V H V H	V H H V
V H V H	V H H V	V V H V	H V V H
V H V V	H V V H	H V H V	V H H V
H V H V	V H H V	H H V H	H H V V

SUBJECT RESPONSE: **VA =** ______

Orientation ___	Orientation ___	Orientation ___	Orientation ___
____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________
____________	____________	____________	____________

SCORING:

20/XX	Orientation 1	Orientation 2	Orientation 3	Orientation 4	Total Correct (X/4)
	____________	____________	____________	____________	___
20	(1,4) H	(1,1) V	(4,1) H	(4,4) V	___
25	(2,2) H	(3,2) V	(3,3) H	(2,3) V	___
30	(3,3) V	(2,3) H	(2,2) V	(3,2) H	___
35	(1,2) V	(3,1) H	(4,3) V	(2,4) H	___
35	(4,3) H	(2,4) V	(1,2) H	(3,1) V	___
40	(2,1) V	(4,2) H	(3,4) V	(1,3) H	___
40	(3,2) H	(3,3) V	(2,3) H	(2,2) V	___
45	(3,4) V	(1,3) H	(2,1) V	(4,2) H	___
45	(4,1) H	(4,4) V	(1,4) H	(1,1) V	___
50	(1,3) H	(2,1) V	(4,2) H	(3,4) V	___
50	(3,1) V	(4,3) H	(2,4) V	(1,2) H	___
55	(2,4) H	(1,2) V	(3,1) H	(4,3) V	___
55	(4,2) V	(3,4) H	(1,3) V	(2,1) H	___
60	(1,1) H	(4,1) V	(4,4) H	(1,4) V	___
65	(2,3) V	(2,2) H	(3,2) V	(3,3) H	___
70	(4,4) V	(1,4) H	(1,1) V	(4,1) H	___

APPENDIX D: BACKGROUND FOR REPORT

INTRODUCTION

Night vision goggles (NVGs) greatly enhance the ability to conduct night operations and are used extensively in both rotary-wing and fixed-wing operations. NVGs provide an intensified image of scenes illuminated by ambient light in the red and near infrared part of the electromagnetic spectrum (approximately 600-900 nanometers [nm]) which exists in the night environment; the intensified imagery is on average at least 2,000 times brighter than the original scene.

NVGs employ an automatic brilliance control (ABC) feature which acts to maintain a constant image brightness by decreasing the intensifier gain in response to input light levels exceeding a defined threshold. Proximate lights emitting energy within the range of the spectral response of the NVG are considered incompatible if they activate the ABC, decreasing intensifier gain. With decreased gain, there is a corresponding decrease in image contrast, and a loss in NVG-aided visual acuity (VA) usually occurs.

Incompatible light can severely degrade NVG-aided VA if the source is within the field of view (FOV) of the NVG. Incompatible light sources outside the FOV also can degrade NVG-aided VA if enough light is captured and internally reflected by the glass elements of the NVG objective lens structure to cause veiling glare. If the veiling glare is severe, it will activate the ABC and decrease image contrast. Even if the veiling glare is not severe, some contrast loss still may occur. Veiling glare generally is caused by incompatible light reflected by cockpit instruments, canopy, or windscreen.

To achieve compatibility and avoid losses in NVG-aided VA due to ABC, cockpit lighting should have a spectral distribution containing little or no overlap with the spectral response of the NVG. Military Specification MIL-L-85762A, Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible, defines criteria for the assessment of cockpit lighting compatibility and categorizes NVGs by type and class. These types and classes are spelled out because NVG-compatible cockpit lighting requirements differ depending on the type and class of goggle being used. The following is a description of the types and classes of NVGs:

a. Type I: Direct view image (e.g., ANVIS)
b. Type II: Projected image (e.g., CATS EYES)
c. Class A: 625 nm minus blue objective lens filter (e.g., ANVIS)
d. Class B: 665 nm minus blue objective lens filter (e.g., CATS EYES)

The main difference between Type I and Type II NVGs is the method by which HUD imagery (stroke and/or forward looking infrared [FLIR] raster) is viewed. A Type I NVG is a direct view system, and both the optics and intensifiers are located in front of the viewer's eyes. HUD imagery may be viewed either directly with the NVG or by turning the head to look around

the NVG with the unaided eye. Viewing HUD imagery directly with Type I NVGs requires that a portion of the spectral output of the HUD be within the response range of the NVG. The NVG then will intensify the HUD imagery, reproducing it in the goggle image. Any loss in contrast or resolution resulting from the intensification process will degrade the quality of the intensified image of the HUD compared to that seen directly with the unaided eye. With Type I systems, the brightness of HUD imagery may need to be adjusted (increased or decreased) depending on how much overlap exists between the spectral output of the HUD and the response range of the NVG.

A Type II NVG system projects the intensified imagery onto semitransparent glass combiners which are located in front of the viewer's eyes; a Type II system is designed to allow unaided viewing of HUD imagery (stroke and/or FLIR raster) through these combiners. Other than the glass combiners, the physical structure of a Type II NVG is located outside the viewer's direct forward line of sight. Intensification of HUD imagery is undesirable with Type II systems. Therefore, Type II systems are designed so there is no overlap between their response range and the spectral output of the HUD. Pilots have multiple options for viewing HUD imagery with a Type II system:

a. Some aircraft are equipped with a system called "auto-scene reject" (ASR). When ASR is selected, the NVG image is extinguished automatically when the goggle is pointed directly toward the HUD and reactivated when the NVG is pointed away from the HUD. With ASR selected, the pilot may view HUD imagery directly through the combiners (without an intensified image). However, the limited transmission of current combiners blocks all but approximately 30% of the visible light, and HUD brightness usually must be increased in order to compensate.

b. With ASR off, the NVG intensifiers operate at all times, and the HUD imagery can be viewed through the combiners concurrently with an intensified image of the outside scene. The same combiner transmissivity problems exist as in option one. However, additional degradation of HUD information will occur due to any mismatch ("boresight error") in the overlay of the intensified image and the HUD raster image. Mismatches are caused by the FLIR sensor head having a significantly different vantage point on the aircraft than the NVG or misalignment of the NVG eyepiece combiner(s) which may occur if a goggle is dropped or damaged.

c. The pilot can view the HUD by looking around or under the combiners.

Class A and B NVGs differ in the spectral characteristics of their minus blue objective lens filter. In general terms, Class A NVGs are filtered so they will not sense and intensify light having wavelengths shorter than the orange region of the spectrum, and Class B NVGs are filtered so they will not sense and intensify light having wavelengths shorter than the middle red region of the spectrum. Therefore, the colors that may be used for cockpit lighting differ between the two classes. MIL-L-85762A identifies three color coordinate ranges for cockpit lighting to be used with Class A NVGs: "NVIS Green A," "NVIS Green B" and "NVIS Yellow." NVIS Green A is used for primary crewstation lighting. However, Green A often is

unreadable under direct sunlight and is not suitable as a color for annunciators or displays for which daylight readability or attensity (ability to attract attention) is crucial. NVIS Green B was established to overcome this shortcoming. It occupies a color coordinate region which is more saturated and provides better daylight readability and attensity. Both NVIS Green A and Green B spectra are outside the response range of Class A NVGs and therefore do not negatively impact NVG performance. NVIS Yellow is a broad band color having spectral characteristics (i.e., some orange content) that slightly overlap the response range of Class A NVGs, and its energy output must be restricted in order to minimize its negative impact on NVG performance. NVIS Yellow is designated for Caution/Warning indicators in Class A cockpits.

In addition to NVIS Green A, NVIS Green B and NVIS Yellow, MIL-L-85762A designates "NVIS Red" (a reddish-orange color) which can be used with Class B NVGs. However, its spectral band overlaps the response range of Class B NVGs, and the radiance of NVIS Red displays must be controlled to limit any negative effect on Class B NVG performance. NVIS Red was established to permit the use of red for Caution/Warning indicators and color moving map displays in Class B compatible cockpits. Although not specifically quantified in MIL-L-85762A, the use of NVIS Red in Class B cockpits should be limited as much as possible because the cumulative effect of multiple NVIS Red annunciators and displays can degrade NVG performance. The amount of NVIS Red can be limited by using NVIS Green B and NVIS Yellow for Caution/Warning indicators. NVIS Red can severely impact Class A NVG performance, and MIL-L-85762A does not allow its use with Class A NVGs.